SPHERICAL BALLOONING

by

Paul James McCullaugh

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Price
One Dollar

By P. J. McCULLOUGH
Saint Louis

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SOME OF THE REQUIREMENTS

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THIS VOLUME
IS RESPECTFULLY DEDICATED TO

OUR BOYS IN FRANCE

WHOSE DEVOTION TO THE BEST INSTINCTS
OF MANHOOD WILL MAKE THE
WORLD SAFE FOR
DEMOCRACY

Foreword

MODERN works on theory and practice in the art of ballooning, not being sufficiently primary to satisfy the average student, this compilation was suggested as a means to assist in an effort to become competent to successfully assemble and pilot the spherical balloon.

Description of equipment herein should not be regarded as covering all methods of design and construction, but is offered as an example of one popular type and system as used at the present day, the object being to impress the fact that in addition to keen observation as to detail in regard to both work and equipment, self-reliance is much to be preferred in preference to theory or suggestions from any other source offered in advance as to just what should be done to maintain control; i. e., problems cannot be solved until presented for solution.

Gas Ballooning

Some of the Requirements

CONSULT the weather man. Arrange for a supply of gas of the proper specific gravity and sand to fill each bag. Secure a complete balloon outfit and check the equipment, making sure that each part examined is in serviceable condition.

One balloon assembly as follows:

One Ground Cloth.
One Balloon Cover.
One Balloon Cover Lace or Rope.
One Balloon Envelope.
One Balloon Appendix.
One Appendix Ring (two parts).
One Appendix Rope Assembly.
One Filling Hose.
One Filling Hose Thimble.
One Rip Cord (red).
One Valve Cord (white).
One Load-Ring Assembly.
One Passenger Basket or Car Assembly.
One Drag Rope.
One Anchor.
One Anchor Rope.

One Sand Bag for each mesh in the circumference of the balloon net, plus six or eight sand bags to hold down the appendix rope cords and the corners of the ground cloth.
Recording Barograph. Barometer. Statoscope. Thermometer. Compass. Watch. Knife. Flash Lamps. Camera. Megaphone. Matches. Pencil. Log. Maps. Money. Water. Lunch. First Aid Kit.

Ground Cloth

Place one corner of ground cloth about five feet from end of gas supply pipe in such position that pipe points diagonally across center of cloth.

Envelope

Unroll balloon envelope so that it will lie diagonally across the center of the ground cloth with the opening for the appendix about four feet from the ground cloth corner which is nearest to the gas filling pipe. The valve end of the envelope should be near the corner of the ground cloth diagonally opposite to that of the gas filling pipe. Pull the folds of the envelope in such way that it will form a disc, so that all of the slack, both on the under side and upper side of the envelope, is evenly distributed in the outer part of the disc thus formed.

Appendix Rings and Appendix

Place appendix rings on the ground cloth with bolt heads down and remove upper ring. Place bolt holes in the cloth of the appendix over the bolts in the lower appendix ring in such way that the inside of the appendix cloth will be next to the lower ring. Place the appendix and lower ring into the balloon. Place bolt holes (which are near the edge of the appendix hole in the balloon) over the bolts in the ring. Put the upper appendix ring in place, making sure that the markers register, as bolt holes are not interchangeable.

Appendix Cord and Loop Nuts

A loop nut is secured to each of the appendix cords which should be twisted five or six times in the opposite direction to that required to tighten the nuts. Turn appendix loop nuts down firmly on the appendix ring bolts, but don't use a wrench or pliers; a small nail or key furnishes quite enough leverage. Both the balloon cloth and the appendix cloth should be inspected to make sure that no folds of the cloth have been clamped between the two appendix rings. Carry the appendix, appendix ring and the folds of the balloon fabric on each side of the appendix ring about half way to the valve opening in the balloon or within about two feet of the center of the ground cloth, keeping in line with the gas supply pipe. Stretch the appendix so that it points toward the gas supply pipe. Place lower edge of appendix ring on ground cloth with upper edge inclined toward the gas supply pipe at an angle of thirty to sixty degrees.

Anchor for Appendix Ring

Place a bag of sand on the appendix ropes at each side of the appendix ring and see that appendix cords on which the sand bags rest are tight between bag and loop nuts on appendix ring.

Filling Hose and Thimble

Place thimble or a joint of stove pipe in end of filling hose, and place both of these into the end of the appendix, making a gas tight joint by binding with a strap or cord. Place other end of filling hose over gas supply pipe and secure in the same way. Place bags of sand on each side of the appendix and filling hose so that the flow of gas is not restricted by the weight of the balloon fabric. Carry folds of envelope on either side of the appendix ring back so that it is again in the form of a disc.

Slack on Under Side Fabric

While doing this, be sure that all of the slack has been taken up on the under side, and that the appendix ring and bags of sand have not been pulled out of position. Pull the cloth or fabric over

to that half of the disc or circle nearest to the gas supply pipe until the fabric at the bottom of the appendix ring has been stretched up over the top of the ring and back to the edge of the balloon nearest to the gas filling pipe. This gives the envelope the appearance, in shape, of the moon in its first quarter. From the inside of the crescent thus formed pull the balloon fabric in the opposite direction until a disc is again formed, the fabric being distributed in such way that the center of the hole for the balloon valve will be about two feet farther from the gas filling pipe than is the appendix ring.

Diameter of Balloon Before Inflating

Shape the balloon fabric so that it forms a disc about two-thirds as large in diameter as that of the balloon when inflated. Be sure that all folds in the balloon fabric are evenly distributed, within two or three feet of the edge of the disc. Remove boots or shoes when walking on balloon fabric. Pull end of rip panel flap and rip cord support flap out through the valve hole.

Slack in Fabric

Rip Cord

Roll the rip cord into a compact ball and tie one end to the flap on the rip panel. At a point on the rip cord, about twelve inches from the rip cord hole in the rip panel flap, tie a piece of cotton wrapping twine and secure same to the rip cord support flap, which is immediately above the rip panel. Pull the balloon fabric back into place so that its disc-like shape is restored. Hold balloon fabric up at rip panel so that rip cord ball can be thrown through the valve hole and caused to lodge near the outer edge on the inside of the envelope.

Valve Cord

Roll valve cord into a compact ball. Hold one end of cord and throw ball through valve hole in envelope so that it lodges on the inside opposite to the rip cord ball.

Net Lay rope ring at valve end of net over the valve hole in the balloon envelope. Separate the net ropes or toe ropes two or three feet apart and pull upper part of net over lower part of net until net ropes have been moved to proper locations. Ropes should be placed as many degrees apart as the number representing double net ropes is contained times in 360; i. e., there should be a distance of 30 degrees between the ropes of a twelve-rope net. Evenly distribute the net over the surface of the envelope and see that the cords of the net—which connect to the rope valve ring—point to the center of the ring. Make a coil of about ten inches diameter with each toe rope and place it with surplus net under the balloon envelope near the edge, making sure that rope coils have not been placed through any of the meshes in the net.

Valve Remove clamp ring from the valve. Tie valve rope to valve cords, and if there is a pair of cords to limit the opening of the valve be sure that they are properly adjusted, otherwise the valve might be rendered useless. Place valve in position with threaded end of bolt up; feel or look around edge of valve to see that valve cords and rope are not looped around the bolts or caught in the valve doors. Place the bolt holes in the envelope over the bolts in the valve and put on the valve clamp ring, observing that location marks register, as bolt holes are not interchangeable. Screw wing nuts down firmly, but do not use wrench or pliers. See that balloon fabric forms a perfect circle with the valve ring. Stretch the balloon fabric at all points around the valve to insure that no folds have been caught under the valve clamp ring. Strap or tie with a string the net rope ring to the valve clamp ring or wing nuts, leaving about one inch slack.

Sand Bags

Hook a bag of sand on every other mesh of the net, each bag being the same number of meshes from the valve or net rope ring. See that bags are located an equal distance apart on the ground cloth so as to form a circle around the balloon. Roll the drag rope into a compact ball with the loop end out.

Inflating

Wrinkles in Top of Balloon

Eliminate all fire. Turn on the gas. As soon as the net begins to tighten pull down on the balloon fabric to remove all large folds or wrinkles near the valve; this should be observed until the balloon is about one-eighth inflated. As soon as the balloon fabric has been forced out against the net by the pressure of the gas, to within one or two feet of the ground cloth opposite each sand bag, the sand bag hooks should be changed so that they are one mesh farther from the top of the net. If there is a wind velocity of over fifteen miles per hour, it is best to make a change of one-half mesh only. After balloon is one-half inflated, there should be a bag of sand on every mesh in a single row of meshes around the balloon. The necessity of hanging a bag of sand on every mesh increases as the velocity of the wind increases; that is, it might be necessary to hang a bag of sand on every mesh before the balloon is one-third inflated.

Danger to Fabric

Remove all bags of sand from appendix ropes before inflation causes undue stress on balloon fabric near appendix ring. When inflation is complete, stop the flow of gas at the supply pipe. Hook all bags of sand on the net so that appendix ring is about three to five feet from the ground cloth. Remove filling hose and thimble from appendix. The next operation requires that you hold your breath to prevent inhaling gas, therefore it is important to concentrate on the following things to be done:

Look up through the appendix. Inspect the valve, valve-cords, valve-rope, rip-cord or rope and rip panel. Locate the rip cord ball and the valve-cord ball. Remove the rip cord ball through the appendix. Unroll and take out all kinks or knots.

Adjusting Rip Cord and Valve Cord

Take hold of the end of the rip cord, reach up through the appendix and push end of cord down from the inside of the balloon through the rip cord hole. Pull through until there is no slack in the rope on the inside of the balloon, then pull about six or eight feet of slack back into the balloon and fasten the rope at the point where it comes through the hole or small appendix, which is about two feet radially from the outside of the appendix ring and directly under the rip panel.

If there is a small eyelet the rope can be secured with a piece of lead pencil or any similar substance used as a wedge. If there is just a hole in the fabric without any arrangement for securing the rip cord, a lead pencil or short stick may be tied to the rope and pushed up endwise and allowed to turn at right angles to the rope while inside of the balloon, in which position it will act as an anchor. If there is a short piece of fabric hose or appendix integral with the envelope, the rope may be tied to the lower end of this with a piece of cotton wrapping twine, forming a pocket into which the slack in that part of the cord which is inside of the balloon may be placed.

String for Rip Cord Support

Any string used to support the rip cord at the rip cord support flap, and at the lower part of the envelope, should be so low in tensile strength that a pull of five or six pounds will cause it to break. Let the valve rope ball down through the appendix and see that the rope hangs properly. Place a string of white cotton wrapping twine—once only—through the loop in the end of the balloon cover lace or rope, and tie it around the appendix. Hold

loosely the appendix rope, balloon cover rope or lace, valve rope and rip cord in a position under the place where the rip cord comes down through the balloon.

Placing Basket or Car in Position

Connecting Basket Ropes

Change position of sand bag hooks in net until there is room to place the basket under the appendix ring. Connect the basket ropes to the load ring in such way that the drag rope toggle is on one side of the basket and outside of the basket ropes. If there is a door or gate in the side of the basket, the drag rope toggle should be on that side. Fold and place basket cover and balloon cover in basket. Remove temporarily a sufficient number of sand bags from the net so that basket can be placed under appendix ring with the drag rope toggle directly under the place where the rip cord comes through the balloon.

Toe Ropes

Connect all net ropes or toe ropes to the load ring. Tie end of rip cord to load ring and place slack into the red bag loosely, beginning near the end which is tied. Tie end of valve cord also, and place it into the white bag in the same way. Change bags of sand one mesh at a time until the first double is reached. After all bags are on the last double, the pilot takes his place in the basket. Hook all bags of sand on toe ropes. The buoyancy of the gas in the balloon should be sufficient to cause the bags of sand to slowly slide over the ground cloth to the basket; if not, remove bags of sand from each toe rope until such movement takes place. Remove all bags of sand from toe ropes and hook them on the basket ropes. Keep load ring level until basket ropes are tight, to prevent the net slipping out of position on the envelope. Place the loop end of the drag rope over the drag rope toggle, and tie the drag rope ball to one of the basket ropes with a cord which should be secured to one of the inner coils of the ball. Aids or students enter

basket and see that instruments and supplies are ready. Remove a sufficient amount of sand to secure an equilibrium. Pull the balloon cover lace or rope and break the string which holds the appendix closed. See that appendix opens before leaving the ground. Wrap the appendix rope loosely around the load ring, opposite to the drag rope toggle. Release the balloon, after which the pilot should have complete control.

Temperature

Assuming the temperature of the atmosphere, and the gas in balloon to be constant and that no escape of gas takes place, except through the appendix and the valve when it is being held open, the task of piloting a balloon is very simple. After striking an equilibrium at any altitude, that altitude would be maintained indefinitely and the balloon would never ascend or descend unless some material substance be released. Loss of gas and change in temperature requires the release of ballast, the amount of which cannot be determined unless conditions are known. The amount of ballast required to recover equilibrium does not depend on the capacity of the balloon, but on the number of cubic feet of gas it contains and the specific gravity of the gas; i. e., if, at the start, one bag of ballast is required to make a correction, it would require but one-half bag to produce the same result if one-half of the gas were lost. This quite often happens after having been in the air for something like 48 hours.

Method of Piloting

The most successful method of piloting a balloon is to constantly observe the statoscopes and release a few ounces of sand as soon as the descent starts, provided the descent is due to reduction in the ascensional force of the gas. If the rate of fall increases, more ballast will have to be released. Momentum will continue to carry the balloon down after the proper amount of ballast has been re-

leased. This sometimes deceives the pilot into releasing too much ballast, after which the balloon will ascend to an altitude greater than the previous maximum altitude. Close observation will assist in preventing a repetition of the same mistake during the flight in question, but as no two flights are alike, an "aiming shot" or two is generally required unless conditions are ideal.

Landing

Having selected a field in which to land, tie the appendix rope to the load ring opposite to the drag rope, which should be unrolled any time at an altitude greater than its length. The rate of descent should be governed by releasing ballast or by opening the valve, remembering that that portion of the drag rope which is on the ground represents the release of that much ballast.

Rate of Fall

Some persons may jump from the top of a twenty-foot wall without injury, while two feet would be the limit for another, so let this fact be borne in mind when deciding on the rate of fall with which the basket is allowed to come to earth.

Ripping

The work of landing is much simplified by pulling down the rip panel. This is absolutely necessary if the velocity of the wind is over fifteen miles per hour, and should be completed by the time the basket is within ten feet of the ground.

Deflating

If there is assistance sufficient to hold the balloon basket so it does not drag over the ground, deflation may be made by valve, which requires much longer. After deflation is four-fifths complete, the valve, valve rope, appendix assembly and rip cord should be removed. When completed, that part of the net on top of the envelope should be removed by pulling the toe ropes over to the valve side of the balloon. Fold balloon envelope by straightening one seam or row of panels from valve opening

to appendix opening and fold each row of panels over this until they form a strip of fabric about two or three feet wide, depending on size of balloon.

How to Roll Net

The net should be straightened out by placing all of the ropes together. Straighten out one row of meshes from the top to the bottom and place each corresponding row with these, after which twist it like a rope and tie with a string at intervals of about ten feet. Load ring should be placed against one side of the basket inside. Coil drag rope loosely in basket, also the net. Hang appendix ring and valve to load ring. Put in appendix, appendix rope and sand bags and put on basket cover. Beginning at the valve end of the balloon (to protect top of envelope from railroad employees' hooks), make a compact roll and lace or tie cover in such way that no part of the balloon fabric can become exposed.

Care of Instruments

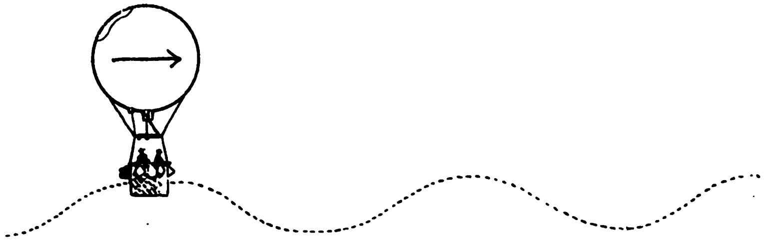
Instruments should be carried and not shipped with the balloon outfit, unless they are well protected by packing in separate boxes.

DIMENSIONS OF SPHERICAL BALLOON

Volume in Cubic Feet	Diameter in Feet	Surface in Square Yards
10,000	26.75	249.77
15,000	30.58	326.42
20,000	33.68	384.75
25,000	36.28	459.14
30,000	38.54	518.52
35,000	40.58	575.34
40,000	42.43	627.55
50,000	45.71	731.11
60,000	48.57	832.55
70,000	51.26	917.30
80,000	53.46	997.62

OSCILLATION

Vertical oscillation of a balloon is generally caused by variation in temperature of the gas. At night the temperature of the air generally diminishes as the altitude becomes greater, this condition remaining relatively constant throughout the night.



Dotted line shows normal oscillation

FIG. 1

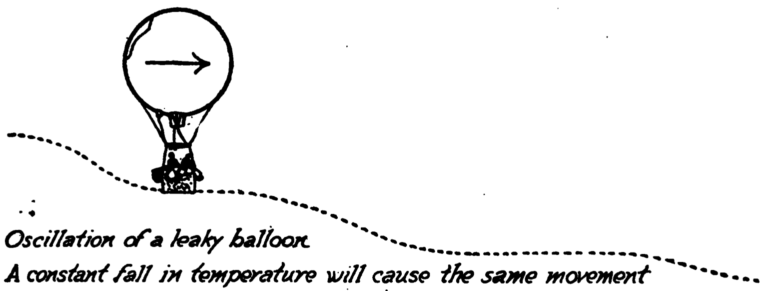
Change in Temperatures

Rate of Oscillation

Assume that at an altitude of 1,000 feet the equilibrium is perfect, after which, due to some irregular air movement, the balloon rises to an altitude of lower temperature, the gas will, of course, contract, causing a descent. However, it will not stop at the 1,000-foot altitude, unless it were possible to provide—from an independent source—some means of stopping the vertical movement at the 1,000-foot mark and holding it there until the temperature of the gas and air equalizes. This not being possible, what really happens is that the momentum and reduction in buoyancy carries the sphere down into the warmer air, where expansion of gas increases specific lightness sufficient to overcome the descending momentum and produce ascending momentum which will not cease until an altitude greater than the 1,000-foot mark has been reached.

The range of oscillation is governed mostly by momentum, and the rapidity with which heat is transmitted between the gas in the balloon and the air in which it floats.

The greater the difference in temperature of the air at different altitudes the more sudden will be the change in the temperature of the gas, which means a smaller range in oscillation. Also, if the balloon fabric is very thin it responds to temperature changes much quicker and acts more sensitive when oscillating than would a heavy fabric, which would, perhaps, oscillate in a range two or three times as great.



Oscillation of a leaky balloon.
A constant fall in temperature will cause the same movement

FIG. 2

Range of Oscillation

Oscillation ranges ordinarily from 25 feet to 500 feet, and will not begin until the temperature of the gas has very nearly approached that of the average of the air. Very close attention is required of the pilot to determine just when oscillation takes place, as the balloon acts identically as it would if it were necessary to release gas or ballast to make the correction.

How to Determine Oscillation

As a rule, when a balloon begins to oscillate, the maximum rate of fall will not be greater than two or three feet per second. Therefore, after—in the judgment of the pilot—the temperature of the gas has become normal, the rate of descent should be allowed to increase considerably above three feet per second before releasing ballast. One should be able to "feel out" these conditions before the altitude has been reduced more than one hundred or two hundred feet.

Leaky Balloon

If a balloon leaks gas, oscillation will represent a movement describing stair steps unless ballast be

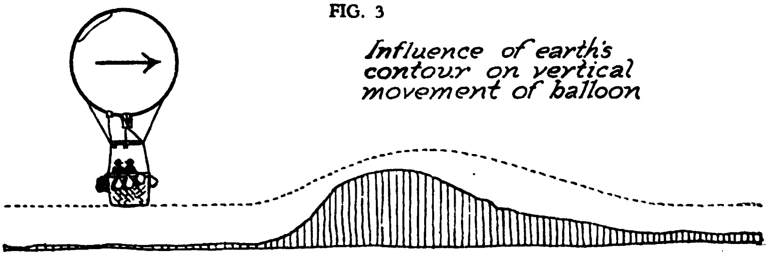
released to compensate for leakage as rapidly as it takes place. Rainfall, even though it be heavy, does not prevent oscillation, it being necessary only to release an amount of ballast equal in weight to that of the water which adheres to the balloon. A steady fall in the temperature of the atmosphere will cause an irregularity in oscillation, similar to that due to a leakage of gas. A rise in the temperature of the atmosphere will cause oscillation describing stair steps ascending and can be corrected by valving or by the use of the blower.

AIR POCKETS

Vertical Air Currents

A term denoting a condition which causes a vehicle of the air to rapidly descend out of control. Vertical movement of the air, due to rapid change of great difference in temperature, is one cause very impressively illustrated by cyclonic conditions.

FIG. 3



Near the leeward side of hills and mountains, or other large objects, will be found a downward movement of air which becomes more decided with an increase in wind velocity. This condition is due to the tendency of the wind to follow the contour of the earth's surface.

Variety in Air Currents

Another condition which mostly affects the heavier-than-air type of air craft may be explained by assuming an aeroplane to be moving at the rate of fifty miles per hour in a stratum of still air, and that the air immediately below forms a stratum which is moving at the same speed as that of the aeroplane, and in the same direction; it is obvious that if the craft comes down into the low stratum that relative to the air it has no horizontal movement and will at once begin to fall.

Relative Movement

If the stratum of air is moving in the opposite direction it will produce the same effect as though

the aeroplane had suddenly increased its speed to 100 miles per hour, a condition demanding wide margin of safety in strength of material and workmanship employed in its construction.

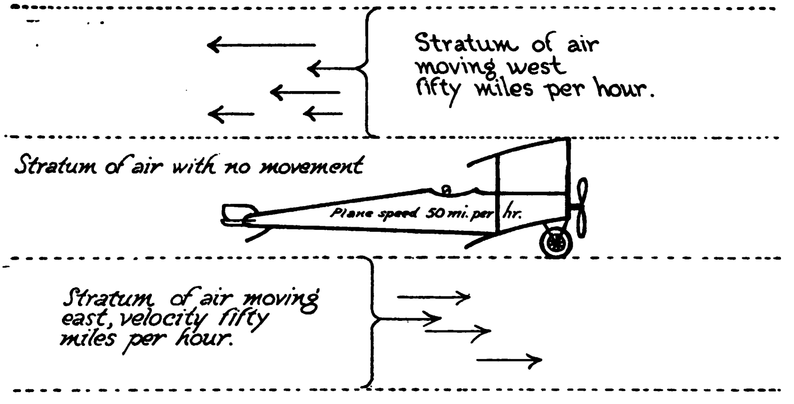


FIG. 4

EXPANSION

All gases expand at a uniform rate (co-efficient of expansion) for equal increment of heat: 1-273 increase in volume for every degree above zero C. So that, assuming an 80,000 cubic feet capacity balloon to be filled with gas that will lift 40 pounds per 1,000 cubic feet, and that a 1-degree C. rise in temperature has taken place, the expansion would be 1-273 of 80,000, or 293.05 cubic feet, with a lifting capacity of 11.92 pounds.

Temperature of Gas

If it were possible to raise the temperature of the gas to something like 240 degrees C., there would be enough gas flow out at the appendix, due to expansion, to fill another balloon of the same capacity. One thousand cubic feet of air weighs 80.73 pounds; 1,000 cubic feet of gás that would lift 40 pounds of ballast would have to be exactly the weight of the difference in pounds between the ballast and air, $80.73 - 40 = 40.73$, the exact weight of 1,000 cubic feet of gas that would lift 40 pounds.

Temperature Conditions

The above figures apply at sea level only. For every degree C. drop in temperature of the gas, there would have to be discharged 11.5+ pounds of ballast to maintain an equilibrium. As a rule, temperature conditions are most variable between the hours of 10:00 A. M. and 7:00 P. M., so that these hours of the day are the most difficult time for piloting a balloon. Ballooning at night is more desirable, because of temperature conditions remaining practically constant. If the sky is clear

from sunrise until eleven o'clock A. M., as a rule the temperature expansion is sufficient to maintain altitude without releasing ballast.

Release of Gas

If the balloon is to be kept at an equilibrium, a sufficient amount of gas must be released at the valve to compensate for the difference in weight between the gas at its initial temperature and a higher temperature; i. e., if at an altitude of 1,000 feet the balloon is at an equilibrium, after which, due to a rise in temperature, 1,000 cubic feet of gas flows out at the appendix, there remains in the balloon the same number of cubic feet of gas, but the lifting power has been increased. This would not be true if we could liquify and freeze the 1,000 cubic feet of gas released, and put it in a sand bag to be used as ballast (it would weigh about 40 pounds); but as this cannot be done, the only thing to do is to release enough gas at the valve to maintain the equilibrium, after which it will be noticed that the lower part of the envelope is somewhat wrinkled because not so much of the warmer gas is required to lift the same load.

Maintaining Equilibrium

Under these conditions it is very difficult to maintain an equilibrium, because unless the valve is used when too much ballast has been released—regardless of how small the excess may be—the balloon will ascend to an altitude where the atmosphere is sufficiently rare to allow the gas to expand and flow out at the appendix sufficient to offset the excess ballast, plus enough to overcome ascending momentum, after which it will at once return to earth unless ballast is released.

Air Blower

The use of a blower (similar to that used by the blacksmith) is often resorted to to keep the envelope fully inflated by introducing air, so that

any increase in altitude will cause gas to flow from the appendix, which eliminates the necessity of opening the valve. The blower is secured to the inside of the basket or car and connected to the balloon with a fabric tube or hose about six inches in diameter. If there is no connection at the balloon for the hose, a thimble should be secured to the inside of the appendix ring, to which the hose may be fastened.

VERTICAL MOVEMENT

When descending from one stratum of air to another, which is moving in a different direction or in the same direction at a different velocity, or not moving at all, the balloon will receive a sudden increase of pressure on the surface of its lower hemisphere sufficient to reduce the rate of fall or cause it to ascend.

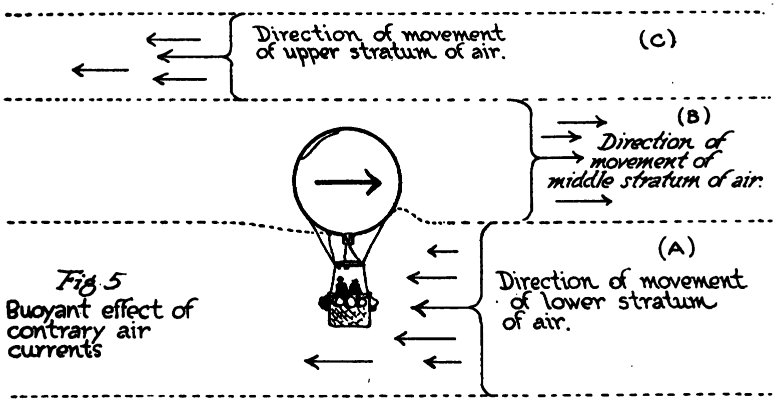


Fig. 5
Buoyant effect of contrary air currents

Buoyant Effect of Air Currents

Great differences in the velocity of air strata will sometimes cause a balloon to seem to oscillate when in fact the gas is contracting. In this event the surprise will come when the excess ballast becomes sufficient to overcome the upward "kick" of the lower stratum and pull the balloon down into it, requiring the discharge of the excess ballast, plus a sufficient amount to overcome momentum after which the pilot generally announces that the balloon has fallen into an "air pocket."

False Register of Statoscope

An irregularity, as described above, is generally accompanied by one in the reading of the statoscope which will register very small differences in air pressure. The false indication is produced by wind pressure against the diaphragm or liquid in the instrument.

When ascending from one stratum of air into another the opposite effect is produced due to the upper surface of the sphere striking the lower side of the upper stratum, where a downward thrust is delivered. This condition is decidedly apparent when a balloon is released in still air and ascends to a stratum of high velocity at low altitude.

Air Strata All variable horizontal air currents are favorable to landing, so far as checking a fall is concerned, inasmuch as the lower surface of the balloon being spherical has a tendency to glance up or away from each stratum which is not moving in the same direction at the same rate of speed. This accounts for the fact that quite often a balloon will act very alarmingly for a time, but on landing it seems to take on life and exhibit sense enough to come down and land beautifully without any coaching or assistance from the pilot, so that—other things being equal—the more contrary the air currents the less difficult it is to keep a balloon at a given altitude, because of the energy displayed by strata No. 1 and No. 3 in keeping the balloon in its stratum No. 2, Fig. 5.

A FALSE START

Vertical Pressure

When a balloon is being "weighed off", its horizontal speed is less than the velocity of the wind which strikes the sphere, divides at its equator and passes over and under, producing a downward pressure on the surface of the upper hemisphere and an upward pressure on the surface of the lower hemisphere, resulting in two opposing forces which are equal when the balloon is at a considerable altitude; but when it is near the earth the pressure on the surface of the lower hemisphere is greater, due to the air becoming compressed between the lowest part of the sphere and the surface of the earth, producing a pneumatic effect sufficient to lift considerable ballast, the amount depending on the velocity of the wind.

If there be no movement of air, the chance of making a false start is very remote. The time required for a balloon to attain its maximum horizontal velocity or zero velocity relative to the wind may be determined by hanging a long string fifty or one hundred feet in length from the basket. The lower end of the string will be in the lead until the balloon "catches up" with the wind, after which the string will hang perfectly straight if the velocity of the wind is uniform. This difference may also be determined by releasing tissue paper.

To Determine Relative Speed of Wind and Balloon

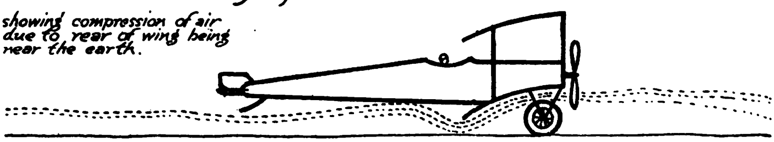
As soon as the balloon is released the pneumatic effect will disappear for two reasons. First: The velocity of the wind relative to that of the balloon reduces. Second: The distance between the earth's surface and balloon is so great that the wedging effect of the wind is no longer apparent, therefore the balloon will fall if the excess ballast is not at once released.

AIR WEDGE AND THE "PENGUIN"

A striking example of the wedging effect of the wind may be observed in the action of the "Penguin," a type of aeroplane used for training purposes. It has just sufficient power to attain an altitude of a few feet only, which is the critical altitude for its maximum speed.

Fig. 6 A Penguin Airplane

showing compression of air due to rear of wing being near the earth.



Leakage

The altitude is limited by a reduction in air pressure between the wings and the earth by what might be termed leakage. That is, assume the earth to represent one side of an air tank which will hold air under pressure. The planes of the aeroplane representing the upper side of the tank, and the openings at the rear, and at both ends between the plane and the earth representing leakage, and the opening between the front edge of the plane and the earth representing the supply opening. It will be observed that if the plane is near the earth that the rear edge will be so near the earth that the leakage would be small compared to the inlet represented by the large opening between the front edge of the plane and the earth due to this edge being much farther from the earth. If the plane were one inch from the earth at the rear edge and ten inches from the earth at the front, or entering edge, the ratio of leakage to that of supply would be one to ten, or 10 per cent, but if the plane

were one hundred inches from the earth the ratio would be one hundred one to one hundred ten, or more than 90 per cent; the comparative leakage being so great that the pressure in the "tank" could not be kept sufficiently high to sustain the weight.

AIR RESISTANCE TO VERTICAL MOVEMENT

Law of Gravity

For example, if an 80,000 cubic feet balloon full of gas at an altitude of 1,608 feet were not supported by the atmosphere or any other substance, i. e., had nothing in which to float, it would fall in accord with the law of the acceleration of freely falling bodies. The first second it would fall 16.08 feet, attaining a velocity of 32.16 feet per second; the second second it would fall a total distance of 64.32 feet, continuing in acceleration until, after having fallen a distance of 1,608 feet, it would have attained a velocity of 321.6 feet per second, or nearly 220 miles per hour. The lifting power of the gas and amount of ballast carried would make no difference, as it would be falling in a vacuum where, if two balloons—one filled with hydrogen gas and the other filled with lead—were released at the same time and same altitude, they would strike the earth at the same instant and at the same velocity.

Speed Limit of Vertical Movement

However, these are not existing conditions, as we have the atmosphere which is not only buoyant but also offers resistance to the relative movement of all substances, so that a balloon containing 80,000 cubic feet of gas, with a lifting power of 40 pounds per 1,000, would be at rest vertically or at an equilibrium with a total load of 3,200 pounds; assuming that 1,000 cubic feet of gas has been released and that no expansion has taken place, the balloon will descend, accelerating in its downward movement until the air resistance, vertically, exactly balances the 40 pounds of ballast which is represented by the 1,000 cubic feet of gas released.

The greatest cross sectional area of a spherical balloon, with a volume of 80,000 cubic feet, is 2,246 square feet, so that an upward pressure of .018— pounds per square foot on the under surface

of the balloon would be required to entirely eliminate acceleration.

Velocity of Fall

Falling at the rate of 4.5 feet per second will produce the above required pressure so that regardless of the altitude the rate of fall cannot be greater than 4.5 feet per second (disregarding difference in density of atmosphere), which is not at all alarming when we remember that, if we jump from a height of eight or ten feet, which is not at all dangerous, we will gain a velocity of about fifteen or twenty feet per second.

Theoretically the ascending acceleration would be limited just the same as descending; that is, if 40 pounds of ballast be released, the speed upward could be no more than 4.5 feet per second, the temperature remaining constant.

Assuming that the appendix rope is tied and that the balloon remains spherical, without releasing ballast the maximum rate of descent would be as follows: After releasing

2,000 cubic feet of gas	5.5 feet per second
3,000 cubic feet of gas	7.5 feet per second
4,000 cubic feet of gas	9.75 feet per second
5,000 cubic feet of gas	10.5 feet per second
10,000 cubic feet of gas	14.5 feet per second

Deflating at Great Altitude

If the rip panel were pulled down at a great altitude, and the balloon allowed to parachute, the maximum rate of fall with a load of 1,200 pounds (the approximate weight of the balloon and two men) would be about 14 feet per second. If the appendix rope is released and the lower part of the balloon be allowed to concave as the gas is released, the rate of fall will be considerably reduced if the descent is rapid.

When to Tie Appendix Rope

Therefore, it is important to make sure the lower end of the appendix rope is not tied to the load ring until coming down to land, at which time it is of great importance to take the slack out of the appendix rope with a pull of about 100 pounds, and

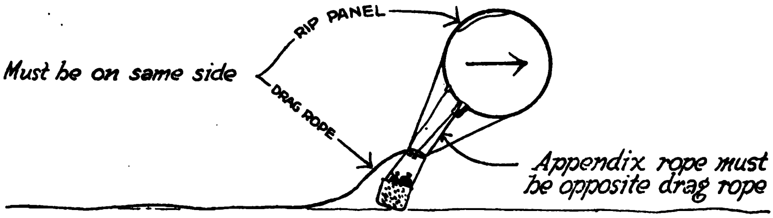


FIG. 7

tie it securely to the load ring, directly opposite to the drag rope, so that the basket will have more of a tendency to remain in an upright position when landing.

LANDING NEAR TIMBER

A Common Mistake

This illustration represents a method of landing in a small clearing in the timber, the difficulty of which increases with the velocity of the wind. A common mistake in making this landing is that of valving too late or releasing too much ballast, resulting in a landing on the far side of the field

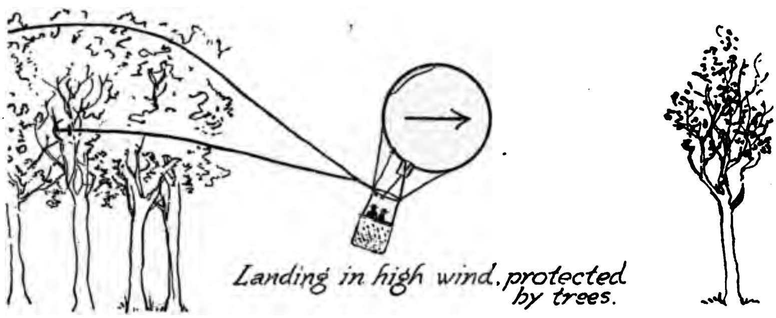


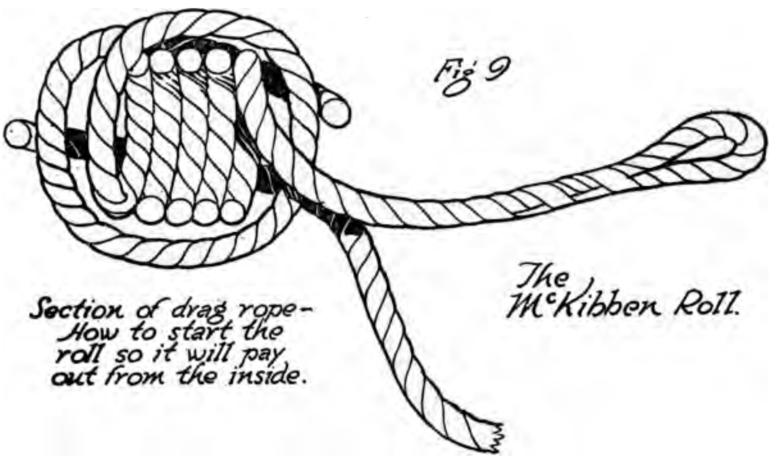
FIG. 8

where the envelope and net might be damaged by the trees. In making a landing of this kind it is best to reduce the altitude to at least the length of the rope before deciding on the landing place, because the chance of a miss and the altitude increases in a direct ratio. That is, the error would be only one-half as great at 500 feet as it would be at 1,000 feet.

FUNCTION OF THE DRAG ROPE

Deflation

The drag rope is nothing more nor less than a brake-rope while it is in contact with the earth, as it brakes both the vertical as well as the horizontal movement of the balloon. That is, it checks the fall and reduces the speed ahead, besides causing the balloon to become so poised when landing that



the rip panel will be at the highest point in the envelope, which insures most rapid deflation when panel is removed.

There is but one correct place to locate the drag rope toggle, and that is directly under the rip panel. (See Fig. 7.)

An automobile may be guided in a horizontal direction only. A balloon may be guided in a vertical direction only, so that the drag rope may also be called the guide rope inasmuch as it automatically guides the balloon vertically when it is in contact with the earth. It also acts as a guide or pointer with which to determine the direction of horizontal movement.

To Roll the Drag Rope

To roll the drag rope, begin about one foot from the loop end and make four coils about four

inches in diameter, forming a convolution as shown in Figure 9. Roll into a compact ball and bind it with about one-eighth inch twine, so that coils do not fall away from the outside of the ball. Secure a stout cord or small rope to one of the coils of rope just below the outside layer and tie it to one of the basket ropes. Be sure and connect loop end of rope to drag rope toggle. Just before releasing the drag rope be sure and remove all of the string or cord from the roll and cut the string which secures it to the basket rope, so that no part of the string falls. This kind of a roll pays out from the inside and does not shake or jar the basket.

Weight of Drag Rope

The drag rope should weigh from 2½ to 5 pounds for each one hundred pounds of the total ascentive force of the gas in the balloon, and should be from two hundred fifty to three hundred fifty feet in length.

THE ANCHOR

If the wind velocity is very high there is nothing certain as to just when an anchor will find something to hold it, therefore it might cause a landing at an undesirable place. Also, if the balloon is carried to an altitude equal to the length of the anchor rope just as it takes hold, the basket will describe an arc and strike the earth with considerable violence, unless an excess amount of ballast be released.

Throwing the Anchor

Never throw the anchor at an altitude as great as the length of the rope, making sure there is something to stop it. The rip panel when used should be pulled down at an altitude of not more than from ten to thirty feet while descending. This is the most convenient method of deflating and should be used in preference to valving, unless it is inconvenient to replace the panel.

Be sure to place all sand ballast in the bottom of the basket along the sides or corner that strikes first, otherwise it may ride the passengers, or if left on the basket ropes will, by its inertia, pull the basket over.

Points on Landing

It is important to place the feet properly on the bottom of the basket, bend the knees, hold on to something substantial, know when the basket will land and keep out of range of the load ring.

NEGLIGIBLE QUANTITIES

Displacement

Difference in ratio of expansion due to temperature between air and gas, which is a very small fraction of one per cent. Difference in the weight of air displaced by ballast and other noncompressible substances, such as pilot aid equipment, etc.; i. e., the air displaced by twelve cubic feet of solid substance would weigh one pound at sea level, but at an altitude of about 18,000 feet it would weigh but one-half pound. Eighty thousand cubic feet of coal gas will lift enough solid substance to displace about four pounds of air at sea level, so that at an altitude of about 18,000 feet the load would be two pounds heavier, because at the greater altitude the air is but one-half as buoyant as it is at sea level.

Loss of Gas Due to Shaking the Basket

Shaking the car or basket by impulsive moving will cause gas to "slop out" at the appendix, but not in sufficient quantities to noticeably rupture equilibrium. However, if such impulsive movement of the car or basket occurs near the critical point of contraction, the net will slip on the envelope, causing it to become more elongated and smaller in diameter, and may cause the loss of a considerable quantity of gas, if it so happens that the envelope is just at the turning point from contraction to expansion.

Compression of Gas

Change in relative density of the gas, due to column compression which varies with an increase or decrease in the vertical diameter of the balloon, i. e., a pear-shaped balloon, would with the same number of pounds of gas have greater ascensional force if the envelope were placed 90 degrees out of vertical. The ascensional force of a sausage-shaped balloon is greater when in normal position than if it "stood on end." The column pressure in any free balloon diminishes as the flight progresses.

At an altitude of 4,000 miles, a 180-pound man would weigh but 90 pounds, so that while ascending the load gets lighter, due to diminishing force of gravity, which does not affect the weight of air in the same ratio.

Location as to latitude is taken into consideration when the weight of air is to be very accurately determined. However, outside of weather conditions, there is no noticeable effect on ballooning.

IF'S

If a sufficient amount of ballast be released a balloon will ascend.

If a sufficient amount of gas be released a balloon will descend.

If ballast be released the balloon will fall, if contraction is sufficiently rapid.

If gas be released the balloon will ascend, if expansion is sufficiently rapid.

If a balloon descends, due to cloud shade, and gas be released, it will ascend if the sun returns sufficiently quick and hot.

If a balloon is ascending and ballast be released, it will at once descend if contraction, due to cloud shade, is sufficiently rapid.

If a balloon is descending, due to cloud shade, it is not necessary to release ballast if the sun comes out sufficiently quick and hot.

If a balloon is ascending, due to sunshine, it will check and descend if a sufficiently effective cloud shade is encountered.

If a balloon leaks gas, gas must be released to maintain an equilibrium if expansion is sufficiently rapid.

If a balloon ascends, due to light load, it will continue until gas flows out at the appendix, unless the correction is previously made by contraction.

If a balloon ascends to another stratum of air, it will receive a thrust tending to force it down.

If a balloon descends into another stratum of air, it will receive a thrust tending to force it upward.

If two or three bags of ballast are accidentally released and the panel is ripped out at from ten to twenty feet on the way **down,** a safe landing will be made.

If two or three bags of ballast are accidentally released and the panel is ripped out at from ten to twenty feet on the way **up,** a dangerous altitude will be attained by the time the gas is all out.

If two bags of ballast are required to check a fall when the balloon is fully inflated with gas, it will require but one bag to make the same correction after one-half of the ascentive force has been lost; i. e., the amount of ballast or gas required to be released when making a correction diminishes as the flight progresses. The same holds good as to the effectiveness of the valve unless air has entered the balloon.

If a flight is made without releasing ballast, the drag rope, to be equally effective in checking vertical movement, should be just two times as heavy as required if one-half of the gas and ballast were released. Therefore, the novice who has lost all of the ballast in an attempt to make a landing will receive much more aid from the drag rope than will the professional who has by constant keen observation succeeded in conserving practically all of the ballast.

If it is required to know the exact amount of ballast and gas to be released to produce certain results, it is necessary to know the total ascentive force of the gas, which force diminishes as the flight progresses. Therefore, it is impossible to furnish tables showing the amount of ballast or gas required to be released in practice to produce certain results, so observe the statoscope and barometer and work accordingly.